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THE USE OF CHEMICALS AS PLANT REGULATORS. AGRICULTURAL CHEMICALS TECHNOLOGY, NUMBER 8.

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ONE OF A SERIES DESIGNED TO ASSIST TEACHERS IN PREPARING POST-SECONDARY STUDENTS FOR AGRICULTURAL CHEMICAL OCCUPATIONS, THIS MODULE IS SPECIFICALLY CONCERNED WITH CHEMICALS AS PLANT REGULATORS. IT WAS DEVELOPED BY A NATIONAL TASK FORCE ON THE BASIS OF DATA FROM STATE STUDIES. SECTIONS INCLUDE -- (1) CHEMICALS AS MODIFIERS OF PLANT GROWTH, (2) TERMINOLOGY AND COMPUTATION, (3) SITUATIONAL AND ECONOMIC CONSIDERATIONS IN USE OF PLANT REGULATORS, (4) CHEMICALS USED AS PLANT REGULATORS, (5) PLANT MODIFICATION PRINCIPLES AND CONCEPTS, (6) PLANT MODIFICATION SKILLS, AND (7) LAWFUL HANDLING, TRANSPORTATION, STORAGE, AND APPLICATION OF CHEMICALS. SUGGESTIONS ARE GIVEN FOR INTRODUCTION OF THE MODULE. RECOMMENDED SUBJECT MATTER, TEACHING-LEARNING ACTIVITIES, INSTRUCTIONAL AIDS, AND REFERENCES ARE GIVEN FOR EACH SECTION. THE MATERIAL IS DESIGNED FOR 24 HOURS OF CLASS INSTRUCTION, 36 HOURS OF LABORATORY EXPERIENCE, AND 60 HOURS OF OCCUPATIONAL EXPERIENCE. TEACHERS SHOULD HAVE AGRICULTURAL CHEMICAL EXPERIENCE. STUDENTS SHOULD HAVE POST-HIGH SCHOOL STANDING, APTITUDE IN CHEMISTRY, AND AN OCCUPATIONAL GOAL IN THE INDUSTRY. THIS DOCUMENT IS AVAILABLE FOR A LIMITED PERIOD FOR $6.75 PER SET (VT 001 214 - 001 222) FROM THE CENTER FOR VOCATIONAL AND TECHNICAL EDUCATION, THE OHIO STATE UNIVERSITY, 980 KINNEAR ROAD, COLUMBUS, OHIO 43212. (JM)

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THE USE OF CHEMICALS AS PLANT REGULATORS

AGRICULTURAL CHEMICALS TECHNOLOGY
No. 8

The Center for Research and Leadership Development

in Vocational and Technical Education

The Ohio State University
980 Kinnear Road
Columbus, Ohio 43212

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RE: (Author, Title, Publisher, Date) Module No. 8, "The Use of Chemicals as Plant Regulators," The Center for Vocational and Technical Education, December, 1965.

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Occupational Focus Goal in the Agricultural Chemicals Industry
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Users of Material Teachers

(4) Requirements for Using Material:
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Student Selection Criteria Post high school level, aptitude in chemistry, high school prerequisite, goal in the agricultural chemicals industry.
Time Allotment Estimated time listed in module. (P)

Supplemental Media --
Necessary x
Desirable
(Check Which)

Describe Suggested references given in module. (P)

Source (agency)
(address)

This publication is a portion of the course material written in Agricultural Chemicals Technology. To be understood fully, the complete set of materials should be considered in context. It is recommended that the following order be observed for a logical teaching sequence:

#1 - The Use of Chemicals as Fertilizers

#2 - The Use of Chemicals as Insecticides - Plants

#3 - The Use of Chemicals as Soil Additives

#4 - The Use of Chemicals as Fungicides, Bactericides and Nematocides

#5 - The Use of Chemicals to Control Field Rodents and Other Predators

#6 - The Use of Chemicals as Herbicides

#7 - The Use of Chemicals in the Field of Farm Animal Health (Nutrition, Entomology, Pathology)

#8 - The Use of Chemicals as Plant Regulators

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THE USE OF CHEMICALS AS PLANT REGULATORS (HERBICIDES EXCEPTED)*

Major Teaching Objective

To develop personal qualities and effective abilities needed for entry and advancement by technicians in occupations which involve the use of plant regulators.

Subsidiary Objectives

1. To develop an interest in and an appreciation of the role which chemicals can have in the production of plants and in the ability of man to modify selected characteristics of plant growth and development by the use of chemicals.

2. To gain an understanding of the principles of plant physiology, plant nutrition, and chemistry important to the study and use by technicians of plant regulators, desiccants, and defoliants in order to accelerate, retard, or otherwise modify plant growth and development.

Suggested Time Allotment

At School		
Class instruction	24 hours	
Laboratory experience	36 hours	
Total at school		60 hours
Occupational experience		60 hours
Total for the Course		120 hours

Suggestions for Introducing the Course

The widescale use of chemicals to accelerate, retard, or otherwise modify plant growth and development is a recent accomplishment in the field of biological science. Only recently has man, through the methods and tools of science, been able to identify, synthesize,

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*Technically, herbicides are classified as plant regulators. However, because of their widespread application, they are treated as a separate unit in this curriculum.

isolate, and make use of chemicals which would yield pre-determined responses in plants. A new field of endeavor awaits those who would exercise a high degree of control over the responses of plants to certain chemical stimuli. It is especially important, in such a rapidly developing field, for the agricultural chemicals technician to become knowledgeable in this important phase of agriculture, to remain proficient and highly competent through study and investigation, and to complement practical experience gained on the job. "Plant regulators are potent materials and can cause much damage and disappointment in the hands of the inexperienced and uninformed."[1]

The following suggestions may be helpful in arousing a high level of interest in the students at the beginning of this unit:

1. Show by pot and flat demonstrations, the effects of various plant regulators, desiccants, and defoliants upon indicator plants. Woody plants, grapes, corn, sunflower, and cotton are plants which have been used. Make no attempt to study chemicals, problems, or responses in detail at this point.

2. Brainstorm with the students and seek to bring out of the session useful and worthwhile changes and modification in plants of various kinds. Attempt to recognize difficulties and obstacles which would be encountered in making these changes and inducing the modification suggested. Identify a number of the "less well known" modifications now possible.

3. Make a survey of local firms and agencies to determine the approximate extent that plant regulators and similar chemicals are used. Ascertain also the purposes for which most of the materials were used. Be sure to include nurserymen and horticulturists.

4. With the help of the students, develop a list of factors which tend to complicate the task of accelerating, retarding, or otherwise modifying plant growth and development through the use of chemicals. By what other ways do we attempt to alter the growth and development of plants?

5. From information obtained from workers in industry, business, public services, and education, develop a list of skills, abilities, and understandings which agricultural chemical

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[1]H. B. Tukey, Plant Regulators in Agriculture, John Wiley & Sons, Inc., New York, N. Y., 1954, p. viii.

technicians need for employment in occupational endeavors which have to do with the use of plant regulators. Suggestions will probably be made for one or more of the following sub-headings:

a. Man's attempt to regulate plant growth and developmental processes by the use of chemicals.

b. Federal, state, and local laws, controls and regulations pertaining to the sale and use of plant regulators.

c. The recognition and identification of conditions and situations of plant growth and development which could appropriately be modified through the use of plant growth regulators.

d. Various chemical resources available for use to modify plant growth and development.

e. Important principles and concepts of chemistry, plant physiology, and plant nutrition upon which plant regulation programs are based.

f. The skills, abilities, and understandings needed to plan a plant regulation program.

g. Important terms, nomenclature, definitions, tables, charts, and guides commonly used and important computations, calculations, conversions, and measurements performed by chemical technologists.

h. Important aspects of handling and applying plant regulator chemicals in the proper manner, using approved methods and equipment.

Competencies to be Developed

I. To develop an interest in and an appreciation and understanding of man's use of chemicals to attempt to modify plant growth, development, and production by means of plant regulators.

Teacher Preparation

Subject Matter Content

Note: Review important aspects of plant nutrition, plant physiology, and chemistry as they relate to the study of plant regulators. Examine what man attempts to do with these chemicals, what some of the problems are, and what the chemical industry is like in respect to plant regulator production and use.

1. Situations which prompt plant regulation

   a. Man's need and desire to use regulators

      1) The highly productive efforts of scientific inquiry and study, particularly during the last 25 years, has resulted in the development of new knowledge regarding the physiological activities in plants. Information concerning new products, processes, principles, concepts, and techniques of inquiry has brought about the possibility of man being able to exercise an ever increasing degree of control over the growth and development of plants. By so doing, he (man) can quite successfully avert or attenuate the consequences of numerous limitations of the environment, weather and climate, market fluctuations, and the natural cycling of many plants.

         (List a number of these factors which in the past have limited plant production and over which we now have considerable control.)

2. Attempts to modify plant growth

   a. Methods of attempting to modify growth and development

      1) The use of chemicals

      2) Control of environmental factors

         a) weather

         b) competition

c) Soil

d) Moisture

e) Nutrition

f) Light

3) Selected cultural practices

a) Moisture control

b) Girdling

c) Thinning

d) Pruning

e) Cutting of growing tips, buds

4) Breeding and selection

3. Review (Materials from previous courses)

a. Plant nutrition

1) Plant nutrients and their role in plant growth

b. Plant physiology

1) Growth processes and principles of plant growth

--Just as man's physical, mental, and emotional behavior is the product of and controlled by hormones, all the tissues and organs of plants require the same kind of coordination as required in higher animals. These too, are controlled by hormones. Many of these hormones are produced in the growing parts of the plant. (Discuss general concepts of hormonal influence.)

c. Biochemistry

1) The chemical processes which take place in plants

4. Introduction to the use of chemicals to modify plant growth and development. (Discuss in general terms only at this point.)

a. Kinds of chemicals available

1) Hormones

2) Auxins

3) Anti-auxins

4) Auxin precursors

b. Examples of plant regulation programs. (Cite local examples if possible.)

1) Extending the growth period of lemons in order to have them ripen nearer to summer demand.

2) Controlling bloom of flowers to take advantage of the Christmas and Easter seasons.

3) Defoliating cotton and soybeans to facilitate harvesting

c. What are the major determinations which need to be made in order to use plant regulators

1) Kind to use

2) Time to use

3) Form to use

4) Amounts to use

5) Placement

6) Method of application

7) Cost

8) Dangers, precautions

d. What results can be expected from the use of plant regulators

1) Crop response

2) Soil response

3) Nutrient level change

e. The importance of using plant regulators

1) Extending adaptability of plant species

2) Economic

f. Problems encountered in using plant regulators

1) Not using correct amounts

2) Not using proper kind

3) Time and placement of application not appropriate

4) High degree of specificity of chemicals

5. The plant regulator industry

a. History and development

1) Review the early work of Darwin and others.

2) Explain the experimentation done with Avena (oat) seedlings.

3) The discovery of hormones, auxins.

4) Summary of investigative work conducted during the 1930's and 1940's. (p. 442 - Bonner)

b. Present status and situation

1) The development of the body of knowledge concerning auxins (synthetic hormones) has given the agriculturists a set of tools for use in plant culture. It is like building a plant to the desired form and then telling it when to bear fruit or even telling it how much fruit to bear.

2) There are now many synthetic compounds which, when applied to plants, bring responses that are qualitatively indistinguishable from those resulting from naturally occurring hormones.

c. Recent changes and future trends

1) The plasticity of the growing plant. The plant scientist of the 20th Century looks upon the major crop plants as so many plastic materials of life that can be shaped and altered by skilled hands. It has become clear that nearly all regulatory processes depend upon underlying chemical activities of cells. Thus, it is increasingly self-evident that anyone who understands the chemical processes of the living cell has the potential power of regulating that cell's activity.

2) Current discoveries are being made for use of chemicals to make trees bear every year (instead of every other year), to control the number and size of fruit on a tree, to finding new and better methods of application.

3) Precursors

4) Inter-relationships

5) Anti-auxins

Suggested Teaching-Learning Activities

1. Prepare and use a display of apical-dominance principle:

   e.g., two plants with terminal buds removed, one of which was treated with growth regulator and one not, and then a third plant with the terminal bud intact. Explain how hormones produced in the terminal bud inhibited the growth of the lateral buds (same as synthetic treated plant) on the plants and how the lack of the hormones inhibiting lateral bud development permitted development of lateral branches on the other plant.

2. Conduct a discussion of how (what processes) it would be desirable to control the growth and production of plants. How could the new set of tools be applied and what advantages could be attained?

3. Duplicate selected phases of the Avena test.

   (p. 23, Auxins & Plant Growth - Leopold)
   (p. 27, Phytohormones - Went & Thiman)

Suggested Instructional Materials and References

Eye-catching newspaper and magazine pictures and articles should be passed among the class to establish a feeling of how dynamic and interesting the field of plant regulators is becoming.

Display--plants showing experimental effects caused by hormones or auxins.

--plants or pictures showing effects of defoliants or desiccants.

Texts - References

Bonner, James, Plant Biochemistry, Academic Press, Inc., New York, N. Y., 1950.

Leopold, Carl A., Auxins and Plant Growth, University of California Press, Berkeley, California, 1955.

Skoog, F., Plant Growth Substances, University of Wisconsin Press, Madison, Wisconsin, 1951.

Tukey, H. B., Plant Regulators in Agriculture, John Wiley & Sons, Inc., New York, N. Y., 1954.

Went, F. W., and Thiman, K. V., Phytohormones, The MacMillan Company, New York, N. Y., 1937.

II. To develop the ability to use important terms, nomenclature, definitions, tables, charts, and guides which are common to the field and also to develop the ability to perform important computations, conversions, calculations and measurements which are used by technicians in the field of plant growth regulation.

Teacher Preparation

Subject Matter Content

Note: This unit is presented here at an early point in the study guide in order that use can be made of it throughout the remainder of the course. It is not intended that it will be taught as a separate competency, as are the other six major units of the course, but that the material presented here will be integrated as appropriate throughout the remainder of the study. The purpose of this section then is to pull together in one section this core of information.

1. Terms, nomenclature, and definitions

Considerable confusion exists in the literature and in practice regarding the use of terms in the field of plant growth substances. Auxins, hormones, growth hormones, growth regulators, phytohormones, gibberellins, growth substances are various names used.

For the purposes of this study, the definitions developed by a committee of the American Society of Plant Physiologists and reported in 1953 are accepted.

a. Hormones (Plant) - are regulators produced by plants, which in low concentrations regulate plant physiological processes.

Comment: Hormones may be thought of as substances produced in certain locations and transferred to other locations and there influence a specific physiological process. They are then chemical messengers. Some authors use the term "correlation carrier" to express the influence exerted by one part of a plant upon another. Phytohormones are synonymous with plant hormones.

b. Plant regulators - are organic compounds, other than nutrients, which in small amounts promote, inhibit, or otherwise modify any physiological process in plants.

Comment: Plant regulator applies to materials that modify any plant physiological process. The term may then be used to describe natural as well as synthetic compounds.

c. Auxin - is a generic term for compounds characterized by their capacity to induce elongation in shoot cells. They resemble indole - 3 - acetic acid in physiological action. Auxins may, and generally do, affect other processes besides elongation, but elongation is considered critical. Auxins are generally acids with an unsaturated cyclic nucleus.

Comment: Auxin is a term used as a group name for chemicals having similar physiological activity. They may be natural or synthetic. Gibberellins are thought to be a special type of auxin. Other specific auxins are identified by their chemical names.

d. Growth regulator - (synonym: growth substance) are regulators which affect growth.

e. Growth Hormones - are hormones which regulate growth.

f. Flowering Regulators - are hormones which initiate the formation of floral primordia, or promote their development.

g. Auxin precursor - are compounds which in the plant can be converted into auxins.

h. Anti-Auxins - are compounds which inhibit competively the action of auxins.

2. Other definitions:

a. Desiccants - These chemicals cause drying of plant parts (the removal of tissue moisture) by chemical or physical action. Their primary use is for pre-harvest drying of living plant parts. For example, in extremely weedy soybean fields, desiccants are used to remove the moisture in both the weeds and soybean foliage. Desiccants are also used prior to combining seed from grasses and legumes.

b. Defoliants - These natural or synthetic chemicals function by inducing the abscission process whereby layers of cells in the abscission zone are formed permitting easy separation of leaves or fruit from the plant. The most widespread use is in the defoliation of cotton to speed and cut costs of harvesting. They are becoming more widely used for the purpose of promoting even ripening in other field crops. Defoliants are also being widely used to thin fruit (either in the blossom or fruit stage).

c. Abscission - the naturally occurring or induced process by which organs or plant parts are separated or shed from the parent plant. The process is important in the survival of the plant and perpetuation of the species. Common examples are leaf fall in the autumn and the shedding of fruit during or at the end of the growing season.

d. Abscission Zone - The specialized region or tier of cells in which the abscission process occurs, usually at the base of organs; for example, the base of the leaf stalk where it joins the main stem. Separation usually results from dissolution (lysis) of cell or cell wall components in this area. Cell division in this region may occur prior to separation but is not essential for separation.

e. Carrier - The application vehicle or agent, such as water or oil, in which the preharvest chemical is applied.

f. Contact Chemical - A compound whose effectiveness is restricted largely to the localized area to which it is applied or which intercepts it.

g. Defoliation - The naturally occurring or chemically induced abscission process by which plants cut off their leaves when they have obtained senescence (old age) or physiological maturity (premature aging). Chemicals used to promote defoliation are known as defoliants.

h. Desiccation - Dehydration or the removal of tissue moisture by chemical or physical action. Drying chemicals that promote desiccation are known as desiccants. They are used primarily for preharvest drying of actively growing plant tissues when seed or other plant parts are developed but only partially mature; or for drying of plants which normally do not shed their leaves, such as rice, corn, small grains and cereals.

i. Inhibitor - A chemical, usually of the regulator type, that prevents or suppresses growth or other physiological processes in plants. An example of a growth inhibitor is 3-amino-1,2,4-triaxole (ATA).

j. Preharvest Chemical - Any contact or regulator compound applied before harvest to improve or maintain quality or to permit and facilitate harvesting the crop.

k. Shedding - Usually used synonymously with abscission, in cotton work shedding usually is restricted to mean the loss of fruiting forms.

l. Systemic - A chemical which is absorbed readily and moved in the plant's vascular (circulatory) system. Plant regulators are of this type.

m. Hormone - "An organic substance produced naturally in higher plants, controlling growth or other physiological functions at a site remote from its place of production and active in minute amounts." (Pincus and Thimann, 1948.)

n. Lanolin - The natural fat of wool; of great value as a carrier for growth substances to be applied to plants, as it is itself without action to the plant.

Note: The instructor may wish to use the following outline to summarize data gathered for inclusion in this section of the study.

(Data presented in this section of the study guide for the course "the Use of Chemicals as Insecticides" may be useful.)

SECTION ONE - General Information

THE STUDENT WILL NEED TO BE ABLE TO:

1. Make use of words, terms, and phrases appropriate to the subject matter of the course. A Glossary of Terms will facilitate this usage.

2. Perform measurements, conversions, computations, and calculations commonly done by technical workers in the field. Tables containing units of measurement and tables of equivalents of units will be useful.

a. Tables of measurement

-- Linear measure - length

-- Square measure - area

-- Cubic measure - volume

-- Liquid measure - capacity

-- Dry measure - capacity

-- Weight measure

-- Temperature measure

-- Time measure

-- Other

b. Tables of convenient equivalents

-- Equivalent volumes - liquid measure

-- Equivalent volumes - dry measure

-- Equivalent weight/volume - liquid

-- Equivalent weight/volume - dry

-- Equivalent lengths

-- Equivalent areas

-- Equivalent weights

-- Equivalent temperatures

-- Equivalent other

SECTION TWO - Information Regarding Agricultural Chemicals

THE STUDENT WILL NEED TO MAKE USE OF:

1. A table which lists the common name, active ingredient, and trade name(s) of chemicals studied in the course.

   Example: G.A. Gibberellic Acid Gibrel, Brellin, Plant Shoot

2. An alphabetical listing of chemicals commonly used in the field. Information such as the trade name, name of major producer, composition, formulation, and recommended use:

   Example: Sevin (Union Carbide Corporation)

   N-meythl-1-naphthyl carbonate, a carbonate insecticide also used as a fruit thinning agent on apples, formulations include emulsions, dusts, WP, aerosol and granules.

3. A listing of chemical materials according to the general use

   Example: Nematocides

   -- chloropicrin

   -- DECP

   -- D-D

   etc.

Rust Fungicides

-- ferbam

-- sulfur

-- maneb

etc.

4. Compatibility charts and tables

   a. Phytotoxicity (with plants)

   b. Chemicals (with other chemical)

   c. Physical (with other chemical)

5. Toxicity tables providing LD and LC values (both oral and dermal, acute and chronic) of chemicals studied in the course.

6. Tolerance limitations imposed by F.D.A. upon residues applicable to the subject matter of the course (i.e., herbicides, insecticides, fungicides, etc.).

What is one part per million?

Most lay people have no conception of what constitutes one part per million residue on crops. The following examples may help you make this interpretation for them:

1. One inch is one part per million in 16 miles.
2. A postage stamp is one part per million of the weight of a person.
3. A one gram needle in a one ton hay stack is 1 ppm.
4. One part per million is one minute in two years.
5. Lay your hand on the ground and it covers 5 ppm of an acre.
6. If one pound of a chemical lands on an acre of alfalfa the hay has 500 ppm. One ounce of a chemical would impart 31 ppm.
7. A teaspoon of material on an acre of alfalfa would impart 5 ppm.
8. One teaspoon of DDT drifting onto 5 acres of alfalfa puts 1 ppm in the hay, and the Federal Law says that the hay must contain none.

(Source--Western Crops and Farm Management)

SECTION THREE - Preparation of Chemicals for Use

THE STUDENT WILL NEED TO BE ABLE TO:

1. Determine whether or not materials prepared and commercially packaged can be applied directly from the container.

2. Determine the total amount(s) of active ingredient(s) contained in a chemical mixture. Mixtures may vary according to weight, volume, concentration, and formulation.

3. Make a determination of the amounts, by weight or by volume, of chemical materials of various levels of concentration to use in order to prepare a given quantity of mixture that will meet recommended or specified dosage or concentration levels. (Weights or volumes of solid or liquid chemicals required to prepare a given quantity of material of different dilutions.)

4. Interpret tables and recommendations for "concentrate" spraying.

SECTION FOUR - Preparation Necessary in Order to Secure Specified or Recommended Application Rates

THE STUDENT WILL NEED TO BE ABLE TO:

1. Compute the area of various plots of land. These plots will vary in size, shape, topography, and planting.

   a. Determine acreage of row planting which vary according to spacing.

   b. Determine total acreage of plots.

2. Determine the speed of a vehicle traveling on the land. (In miles per hour and feet per minute.)

3. Three variables affect the application rate of agricultural chemicals secured in the field - the speed of travel, the effective width of the device applying the chemical, and the total material delivered per unit of time. If two of these variables are known, calculate the other in order to secure a specific application rate.

   a. Calibrate sprayers, dusters or metering devices to secure specific delivery rates.

   b. Compute the length of boom, number of outlets, or width of opening to secure specific widths.

   c. Calibrate ground speed to secure specific rate of forward travel.

4. Use tables of "Rate of Equivalents"

   Example: 1 ounce per square foot = 2722.5 pounds per acre

5. Calculate the quantity of spray per length of row (on various spacings) which will be equivalent to a specific application per acre.

6. Determine the gallons per acre required to spray orchards of different planting distances.

7. Consider the effect of particle size on drift and deposit. (Prepare spray drift and deposit table.)

SECTION FIVE - Information Relative to Diagnosis and Prescription

THE STUDENT WILL NEED TO MAKE USE OF:

1. Tables, charts, and guides which summarize situations encountered in agricultural production in which the use of chemicals is appropriate. Materials to use and methods of application are suggested.

   Examples of form used:

Plant or Soil	Pest, Disease or Condition	Causative Agent or Factor	When to Treat	What Material to Use
Peach	To accelerate ripening		Prior to commercial maturity	NAA

Active Ingredient	Formulation	Amount Concentration Req'd per Acre	Method of Application	Remarks
400 mg/ kg fruit	Solution	NA	Water dip	

2. Graphs, charts, tables, and other illustrative materials available and supportive of the unit under consideration.

   Examples:

   a. Graphical relationships

      -- time versus residue levels

      -- rates of application versus levels of effectiveness

      -- levels of concentration versus levels of effectiveness

      -- stage of development or growth versus effectiveness of chemical control, etc.

SECTION SIX - Sources of Information

1. Chapter five of Plant Regulators in Agriculture by Tukey has a number of tables and charts which contain information relative to useful measures and equivalents. The calibration of sprayers is also discussed and illustrated. The table on the influence of growth regulator applications on maturity and ripening is recommended. (pp. 134-140)

2. Chemical Weed Control Equipment - California Experiment Station Circular 389.

3. P. 342, Auxins and Plant Growth, by Leopold. (Auxins and other plant regulators commonly recommended for agricultural applications.) This reference contains a large number of figures which present results of field work and experimentation over a wide range of topics.

4. Unit two of the study guide for the course "The Use of Chemicals as Insecticides" in this curriculum is recommended.

III. To learn to recognize and identify situations and conditions related to the growth and development of plants which could appropriately be modified by the use of plant regulators, and to understand the economic importance and to anticipate some of the outcomes of using such chemicals.

Teacher Preparation

Subject Matter Content

1. Situations and conditions appropriate for plant regulation

   a. Agriculturists are often motivated to modify or alter the growth and development of plants. Some of the reasons for this are:

      1) To take advantage of prices and market situations

      2) To offset changes in demands for products

      3) To minimize the effects of weather and other environmental changes

      4) To increase quality and quantity of produce

      5) To facilitate harvesting

      6) Other

   b. Plant regulators can be used at the election of the agriculturist to:

      1) Control fruiting cycles

      2) Extend the vegetative growth period

      3) Control the persistence of fruit/seeds

      4) Control the abscission of flower, fruit, leaves

      5) Control the length of the flowering period

      6) Control the period of flower initiation

      7) Control the rate of growth

      8) Induce fruit set

      9) Control amount of fruit set

10) Control maturation of fruit, seeds

11) Initiate new organs

12) Stimulate new growth

13) Control dormancy

14) Alter chemical make-up of the plant

15) Prevent pre-harvest fruit drop

16) Delay foliation

17) Parthenocarpically set fruit

18) Induce mutations, alter genetic constitution

19) Control keeping qualities for storage

c. Use of plant regulators

1) Use to control abscission of flowers, fruit, leaves

a) Use to prevent pre-harvest drop of fruit. Used primarily in pome and citrus fruits

b) Use in fruit thinning, especially apples. Provides larger fruit of high quality and trees are more likely to bear fruit every year.

c) Prevention of blossom drop

d) Use to thin bloom

2) Use to control dormancy and preserve in storage

a) Use to prevent spoiling in storage

b) Prevent sprouting of nursery stock, trees, and shrubs in storage; aids in transporting and in transplanting

c) Prolong dormancy of fruit trees until frost free date

d) Use to induce early budding

3) Use to control size and maturation of fruits, induce fruit set. (Why induce parthenocarpy?)

a) Overcome limited fruit set due to no pollination

b) Delay loss of flower by abscission

c) Increase the rate of maturing of the crop

d) Increase the size of the fruit

e) Increase the rate of ripening of stored fruit

4) Use when grafting and pruning

a) Promotes cell division; help form callus, thus promotes uniting of the stock and scion in grafting

b) Heal wounds caused by pruning

c) Use to induce or prevent suckering or bolting

5) Use to initiate new organs

Use in plant propagation--rooting cuttings, layering and leaf cuttings.

6) Use to control size, shape, and suckering of plants

a) Controls influence of apical dominance

b) Use to increase or decrease internode length

c) Use to sucker plants

d) Use to strengthen crotch angle in fruit trees

7) Use to control flowering

a) Induce flowering, helps make uniform crop

b) Control untimely flowering in vegetables

c) Prolong period of flower blooming

8) Use to improve color and qualities of fruit

a) Improved coloring is side effect from use of auxins

b) Use to produce seedless fruit of equal quality

c) Thin fruit to improve size, color, shape

9) Use to protect against temperature extremes

a) Frost protection and resistance

b) High temperature resistance

d. Defoliants and Desiccants

1) Types to use

a) True defoliants - use to cause leaf fall with a minimal drying

b) Defoliants and desiccants - result depends largely on the rate of application

c) True desiccants - induce rapid killing and drying with minimal leaf drop

2) Use of pre-harvest chemicals in cotton

a) Speeds harvesting operation, reduces cost

b) Permits machine stripping

c) Stops active growth and causes uniform ripening

3) Use of chemicals on small seeded legumes

a) Reduce succulent foliage of both the crop and associated weeds, allows direct combining

b) Spray cured alfalfa is more tolerant to wind damage and seed losses are much lower

c) Minimizes the amount of specialized harvesting equipment necessary and reduces time to complete harvesting

d) Lowers seed loss

e) Crop ripens more evenly

4) Use on soybeans

a) Pre-harvest sprays are practical only in extremely weedy fields or to promote ripening

5) Nursey stock

Defoliants are used for nursey stock to permit easy fall digging

2. Limitations and problems with plant regulators, desiccants, and defoliants

a. Dangers from contamination of chemicals in sprayers

b. Difficulty to obtain adequate coverage in terms of placement and amount

c. Drift and danger to adjacent crops

d. High specificity of many chemicals

e. Danger of injury to the crop because of the interaction of so many variables involved.

f. Extremely small amounts generally needed

g. Danger of injury to other parts of the plant not being treated.

h. Poor results in some instances of seed production and root stimulation (lower yields and abnormalities).

i. The possibility of undesired or deleterious responses to overdose is present.

j. A lack of data from field work upon which to base judgments and decisions (due to the newness of many of the chemicals).

Suggested Teaching-Learning Activities

1. On the basis of market prices charted by the students for a two-year period, have the class determine the increase in earnings possible by having produce ready for a seasonal market two weeks ahead of the usual time.

2. Have members of the class report about chemical control programs with which they are familiar.

3. Analyze the production practices of the area with the thought of making a determination of how plant regulators could benefit producers.

4. Invite a local producer or chemical technician to give the class a lecture - demonstration on how the use of plant regulators influences their business.

5. Assign each member of the class different demonstrations to perform on the use of plant regulators as suggested in this unit. Fifteen or 20 demonstrations should be prepared.

Suggested Instructional Materials and References

Instructional material:

1. Charts showing market or price fluctuations to emphasize the importance of maturation dates.

2. Charts showing price variation in size and quality of produce.

3. Newspaper and magazine articles telling of economic losses that may have been avoided with the proper use of chemicals to control date of flowering, maturing, etc.

4. Graphs showing examples of increased returns vs. cost of chemicals.

References:

Controlling Abscission of Flowers, Fruit, and Leaves - p. 83 of Hormonal Control of Plant Growth by Parihar

Control Size and Maturation of Fruits - p. 86 of Hormonal Control of Plant Growth.

Inhibition of Growth - p. 216 of Growth of Plants, Crocker.

Plant Regulators in Agriculture, Tukey.

Suggested Occupational Experiences

1. Experience in greenhouse or nursery either in sales or in plant care.

2. Experience in chemical research project involving plants.

3. Experience in chemical sales of plant regulators, defoliants, and desiccants.

4. Experience in harvesting or marketing of vegetables and fruits.

IV. To become knowledgeable, at the technical level, regarding the various chemicals used as plant regulators.

Teacher Preparation

Subject Matter Content

1. Classification of chemicals used as plant regulators
   a. According to the plant process regulated
      1) Cell elongation, cell division - growth
      2) Flowering and fruit development
      3) Tropisoms
      4) Inhibition
      5) Control of abscission
      6) Morphological differentiation
   b. According to chemical make-up and pharmolcology
      1) Indoleacetic acid
      2) Indole derivaties other than indoleacetic acid
      3) Napthalene derivatives
      4) Phenoxyacetic acid derivatives
      5) The substituted benzoic acids
   c. According to source
      1) Natural
         a) Plant
         b) Animal
      2) Synthetic
   d. According to forms and sources in plants including precursors and derivatives
      1) Free growth substance
      2) Precursors of growth substance

3) Bound growth substance - in form of derivative

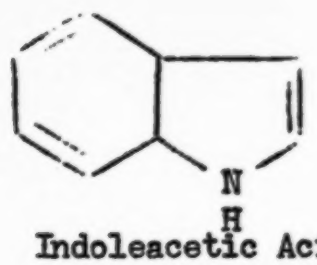
4) Protein-bound growth substance - combined to native protein

2. The chemical nature of plant regulators, desiccants, and defoliants

a. The chemistry and identification of native plant regulators

1) Indoleacetic acid

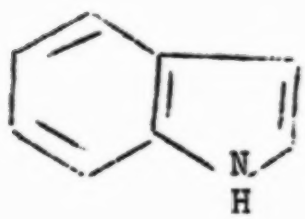
This acid is the only true growth-promoting hormone definitely to occur naturally (Thimann Bonner)



Indoleacetic Acid
3-Indoleacetic acid
beta-Indoleacetic acid
3-Indolylacetic acid
beta-Indolylacetic acid
Hetero-auxin
"IAA"

a) Precursor of indoleacetic acid

Tryptophane

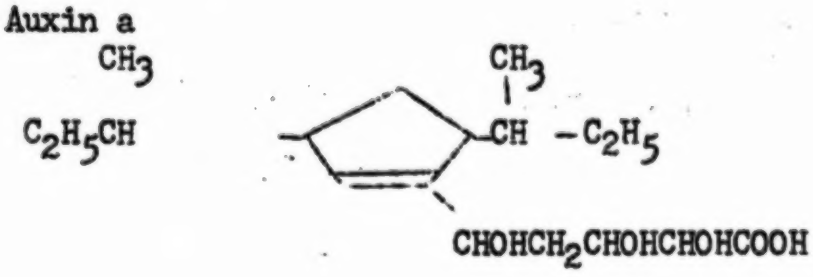


b) Related complexes

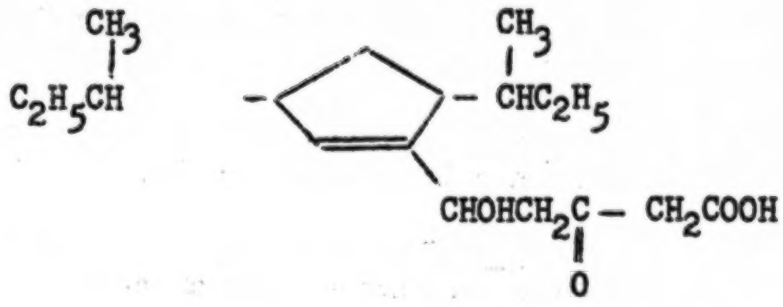
1a) bound in endosperm material of corn and wheat

1b) bound in radish, protein of leaves, wheat embryos

2) Auxin a



3) Auxin b



b. Synthetic plant regulators used in agriculture

1) Derivatives of indoleacetic acid

a) Indole

b) 3-Indoleacetamide "IAD"

c) 3-Indolepropionic acid "IPA"

d) 3-Indolebutyric acid "IBA"

2) Napthalene derivatives

a) 1-Napththalene acetic acid "NAA"

b) 2-Napththoxyacetic acid "NOA"

c) Alpha-Napththylacetmide "NAd"

d) alpha-Napththylproponic acid

e) Methyl Napththaleneacetate "MENA"

f) alpha-Napththalenebuytric acid "NB"

3) Phenoxyacetic derivatives

a) Phenylacetic acid "PA"

b) Phenoxyacetic acid

c) 2,4-Dichlorophenoxyacetic acid "2,4-D," "DCPA"

d) 4-Chloro

e) 2,4,5-Trichloro "2,4,5-T" "TCPA," "TCP"

f) 2 Methyl-4 chloro "MCPA," "MCP"

4) Salts, esters, and amides

Many derivatives of 2,4-D and other related acids are used in agriculture. Improved physical properties are obtained in a number of salts, esters and amides.

A salt is the compound formed by the reaction between a base and an acid.

An ester is the compound formed by the reaction between an alcohol and an acid.

An amide is the compound formed by the replacement of the OH group in an acid by the NH_2 group.

a) Salts	b) Esters	c) Amides
Sodium	Methyl	3-indoleacetamide
Ammonium	Isopropyl	alpha-naphthalene-acetamide
Triethanolamine	Butyl	2,4-dichlorophen-oxyacetmide
Triethylamine	2-Butoxyethyl	
Monoethanlamine	n-Amyl	
Ethylamine	n-Hexyl	
Morpholine		

5) Other materials - materials not meeting the requirements of the definition of hormone or growth regulator are also used in agriculture to secure effects of economic importance. Some of these materials include:

a) Calcium cyanamid

b) Sodium cyanamid

c) Ethylene chlorohydrin

d) Thiourea

e) Colchicene

f) Acenaphthene

3. Guide for the study of agricultural chemicals

Note: The instructor will determine which chemicals are to be studied in depth. This selection of course depends upon the requirements of local areas and situations. Other items should be added to the guide as appropriate.

a. Chemical name (active ingredient)

b. Empirical formula

c. Chemical service

d. Common name

e. Trade name(s) and major producer(s)

f. Melting point

g. Vapor pressure

h. Solubilities

i. Odor

j. Color

k. Density

l. Physical state (liquid, solid, gas)

m. Corrosive action

n. Flammability

o. Stability

p. Compatibility

q. Suitable diluents

r. Concentrations

s. Purities/grades

t. Mixtures available

u. Industrial preparation

v. Formulations for use/additives used

w. Analytical methods

x. Analysis of mixtures

y. Phytotoxicity

z. Toxicity (LD_{50}, LC, ppm oral, dermal, acute, chronic)

aa. Special hazards

bb. Residues likely, tolerance limitation

cc. Synergists possible for use

dd. Intended general use (insecticide, fertilizer, nematocides, etc.)

ee. Intended specific use

ff. Antidotes and first aid

gg. Factors which limit the effectiveness of the chemical (such as temperature, sunlight, water, etc.)

Suggested Teaching-Learning Activities

1. By pot and flat demonstration and experimentation, show the results of using various kinds of regulators on different species of plants. Vary concentrations, age of specimans used and intended purpose of using the chemical.

2. Secure samples of the chemicals used as growth regulators. Study solubility, spreading action, volatility and other physical and chemical characteristics.

3. Visit a research facility to examine what is being attempted to develop additional chemical regulators and also to find new applications of plant regulators.

Suggested Instructional Materials and References

Texts - References:

Bonner, James, Plant Biochemistry, Academic Press, Inc., New York, N. Y., 1950.

Leopold, Carl A., Auxins and Plant Growth, University of California Press, Berkeley, California, 1955.

Skoog, F., Plant Growth Substances, University of Wisconsin Press, Madison, Wisconsin, 1951.

Tukey, H. B., Plant Regulators in Agriculture, John Wiley & Sons, Inc., New York, N. Y., 1954.

Improving Grape Quality, California Agricultural Experiment Station Extension Service.

Oil and Oil Emulsion for Sucker Control in Tobacco, Virginia Polytechnic Institute.

Plant Propagation and Root Stimulation, pp. 210-215 in Growth of Plants, Crocker.

A New Cotton Defoliant and Crop Desiccant from Union Carbide, Union Carbide Corp.

V. To gain a knowledge and understanding of the principles, concepts, and general practices related to the use of chemicals to modify plant growth and development.

Teacher Preparation

Subject Matter Content

1. Plant growth correlation

The growth of the cells, tissues, and organs in a plant are not haphazard as the various parts grow and develop in relationship with one another. Growth of the terminal bud influences the subsequent development of lateral buds, the activities of leaves influence the production of flowers, food produced in one part of the plant is translocated into other parts and water absorbed by the roots is moved throughout the organism. Man, through the use of natural and synthetic plant regulator substances, attempts to bring about desired results through the modification and alteration of the physiological processes which naturally occur in a plant.

The attainment of desired results by the use of plant regulators is limited and altered by a number of factors, some of which can be controlled and many that cannot. Each should be studied in detail.

a. The chemical used
   1) Kind
   2) Form and formulation
   3) Amount to use - concentration
   4) Amount to use - total
   5) Specificity
   6) pH of chemical

b. The application made
   1) Type of method
   2) Rate
   3) Temperature, wind, moisture

c. The plant

1) The variety, species

2) Movement of chemical into the plant

a) absorption affected by -

-- condition of foliage/dry/wet/waxy

-- shape of foliage

-- density of foliage

-- carrier used

-- temperature

-- light

-- rain

-- soil structure

-- soil moisture

-- soil texture

b) Translocation affected by

-- temperature

-- light

-- effect of carbohydrates

-- movement by capillarity in selected medium

-- molecular structure

-- actual rate

c) Status of the plant affected by

-- age

-- stage of growth and development

-- size

-- nutritive condition

3) The environment

a) Temperature

b) Light

c) Relative humidities

2. Effects of plant regulators on growth and development

Leopold[1] suggests that the effects of endogenous auxins may be grouped into six general classes:

a. Growth

1) There are differences in the specific auxin levels required to stimulate growth in different plant organs.

2) Roots have a higher sensitivity to auxin than stems and are thus stimulated to grow by much lower concentrations than those required to stimulate growth of stems.

3) There are some concentrations of auxin which promote growth of stems which inhibit the growth of buds and roots. Lower concentrations can promote the growth of buds and still lower concentrations can promote the growth of roots.

4) The dualism in the action of auxin to stimulate or inhibit is primarily a function of the effective auxin concentration in the tissue.

b. Tropisms and plant movements

1) Phototropism

a) Curvature of a growing plant toward a light results from unequal distribution of auxin. This unequal distribution is caused by a lateral translocation of the plant regulator.

b) Light causes a desensitization of growing cells to a given amount of auxin.

c) Light can bring about auxin formation.

d) Auxin is destroyed by some wavelengths of light.

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[1] Leopold, A. C., Auxins and Plant Growth, University of California Press, Berkeley, 1955, p. 94.

2) Geotropism

a) Lateral transport of auxin has been shown to be caused by exposure to lateral gravitational forces.

b) Auxin is formed in meristems located just above each node of sugar cane stems after geotropic stimulation and horizontal placement.

3) Root Tropisms

a) Tropisms in roots are apparently controlled by the same mechanisms as are tropisms of coleoptiles and shoots, except that the direction of response is reversed.

b) Roots have a very low optimum auxin concentration for growth.

c. Inhibition Effects

1) Manifestations of action

a) Apical dominance -- effect on lateral bud growth

b) Coleoptile growth

c) Stem growth

d) Root growth

e) Dormancy

f) Flowering

g) Abscission

2) Inhibitance associated with

a) Low levels of auxin which in turn can be caused by a high rate of destruction by

-- anti-auxins

-- auxin antogonists

-- irradiation

-- change in the photoperiod

b) Low levels of auxin which can be the result of a low production rate in the plant

c) High level of concentration of auxin brought about by natural production.

d. Organ Differentiation

1) Kinds of growth and development found in plants

a) Cell elongation

b) Shape, thickness of cell wall -- callus

c) Root formation

d) Meristem formation

e) Vegetative bud formation

f) Flower bud formation

2) The kind of growth and differentiation is dependent upon:

a) Concentration of the auxin -- an organ may be promoted by one range of concentration and inhibited by another

b) Presence of other compounds -- the interaction between an auxin and other compounds in a plant is dependent upon the kind of compound and the ratio of the amount of each. Bud, callus, or root formation results from variations.

c) Kind of tissue - tissues of different chemical composition yield different organs.

e. Fruit development

1) Auxins are capable of setting fruit in many species without pollination

a) The role of auxin in this process appears to be associated with the incitement of growth of the young fruit and the prevention of abscission of the flower.

f. Abscission

1) Kinds of abscission controlled

a) Leaf

b) Flower

c) Fruits

d) Stems

2) Action of auxin on abscission

a) Accelerate or retard depending upon time and location of application

-- Auxin applied on the distal side of an abscission layer retards abscission.

-- Auxin applied on the proximal side accelerates abscission.

3) Control of abscission is dependent upon

a) The content of auxin in the organ which may be abscissed. Use is made of this principle in the use of desiccants and defoliants. The auxin producing capacity of the organ is altered - hence abscission is controlled.

b) The gradient of auxin levels between the organ and the stem to which it is established.

3. General use of plant regulators

a. Application

1) The usual means of applying plant regulators is in aqueous solution.

2) Applied auxins are generally most effective in acid solutions of a pH from 3 to 5.5.

3) When working with crystalline auxin, allowance should be made in weighing for the water of crystallization. As much as 35% error can be introduced if this is neglected.

4) Since it is difficult to put crystalline auxin into solution, a few milliliters of ethyl alcohol are often used and then water is added as necessary for the proper volume.

5) It is often helpful to apply auxins with carriers such as carbowax, detergents, or wettable powders.

6) Bomb type aerosol dispensers are used to apply growth regulator sprays.

7) Lanolin paste and talc preparations are sometimes used to apply auxins.

8) Methods of application include

-- direct spray on the foliage (difficult to control amounts applied)

-- infiltration into the leaves (limited primarily to lab work)

-- injection into the fleshy parts

-- immersion of plant parts into solution

-- incorporation with other chemical sprays (auxins seem to be compatible with most spray materials provided they do not contain lime).

9) Auxins vary a great deal in their effectiveness to promote various responses in plants.

b. Persistence

1) Indoleacetic acid is spontaneously inactivated to a certain extent in solution. Crystalline indoleacetic acid in time breaks down and turns brown as it does so.

2) Store dry crystals. Solutions breakdown rapidly, noticeable changes are observed in ten days time even under refrigeration.

3) Auxins which have been applied to plants generally remain active for a limited time -- 1-10 days although auxins vary considerably in this regard.

4) Although some morphological defects do not become evident in some crops for as long as a year after application of auxins, most irregularities are usually established within a few days.

c. Rooting

1) The balance between auxins and other plant constituents as the control of differentiation is the physiological basis for the rooting of cuttings.

2) Auxins stimulate root formation by an interaction involving organic materials in the plants, particularly carbohydrates and nitrogenous materials.

3) The use of plant regulators in concentrations higher than optimum results in a reduction of rooting.

4) Several environmental factors influence the ability of a cutting to root.

a) Season -- varies greatly from June sapwood to winter woody cuttings.

b) Photoperiod exposure -- periods experienced by the stock plant especially important.

c) Light -- rooting inhibited if entire stock is exposed; red light more effective than blue.

d) Temperature and aeration -- low temperatures stimulate callus; root formation stimulated by high temperatures; good aeration is essential to good rooting of cuttings.

e) Humidity -- high humidities favor rooting.

f) Variety and species of plant.

d. Parthenocarpy

1) The period when greatest effectiveness to set fruit parthenocarpically in the tomato (When the petals just begin to open) is several days before maximum response to pollen occurs.

2) The first flower to open in a cluster responds best to auxin treatments.

3) Sprays applied to the face or front of the flower result in fewer fruit abnormalities than sprays applied at more distant points.

4) Benefits accruing from using auxins to set fruit include:

a) Make up for failure of pollination

b) Delay loss of flower

c) Make possible an earlier crop

d) Increased fruit size

5) Conditions under which auxins may be used effectively to set fruit parthenocarpically

a) Weak light

b) Excessive temperatures

c) High nitrogen content

d) Low leaf areas

e) Conditions favoring abscission of flowers

6) Possible difficulties of forced parthenocarpy

a) Leaves tightly curled

b) Deformed fruits

c) Hollow or puffy fruit

d) Seedless fruit common

e) Fruit susceptible to bruising

7) Tomatoes and figs are crops most widely treated

e. Flower and fruit thinning

1) Need of thinning

a) To regulate the number of flower buds set each year in order that some fruit trees will be annual rather than biennial in bearing habit.

b) Reduce heavy fruit set to increase size and quality of fruit.

c) Reduce heavy fruit set to aid in insect and disease control.

d) Reduce heavy fruit set to protect the tree from excessive weights.

2) Thinning results from

a) Prevention of natural pollination

b) The abortion of young embryos

c) The direct forcing of abscission

3) Effectiveness of thinning is dependent upon

a) The vigor of the tree

b) The nitrogen level of the plant

c) Age of fruit at the time of spraying

d) Quantity of fruit set

4) General

a) The very high specificity of auxins is shown by the fact that some varieties will set fruit partheno-carpically while other varieties of the same species will lose flowers when treated with the same plant regulators.

b) The optimum time to secure maximum effectiveness for auxin use for thinning is extremely variable according to species.

c) Increased cold-hardiness the succeeding winter season comes about as a result of fruit thinning.

d) Apple and peach trees give most satisfactory responses to the use of auxins for thinning fruits or flowers.

f. Control of pre-harvest drop

1) Need for control

a) Losses through excessive wind

b) Losses through hot weather

c) Lack of auxin production upon ripening

d) Hold fruit for more favorable market price

2) Effectiveness of controlling pre-harvest drop depends upon

a) Severity of the fruit drop which would occur without treatment

b) Weather (temperature extremes and wind especially)

c) Nitrogen level

d) Size of crop

e) Vigor of the tree

f) Moisture levels

3) General

a) Increased coloring is secured in apples following auxin treatment; however, some increase in respiration may also result in some varieties (hence alteration of ripening and storage qualities).

b) Prevention of fruit drop by use of plant regulators has been secured in apricots, pear, apples, orange, grapefruit, lemon, and almond.

g. Flowering

1) The need to regulate flowering

a) Accelerate maturation process

b) Induce flowering

c) Retard flowering

d) Prevent flowering

2) Regulation achieved by

a) Spray applied to vegetative parts (pineapple)

b) Foliar application at normal time of flowering

c) Soaking of seeds

3) Control of flowering is dependent upon

a) Concentration of plant regulator

b) Variety and species

c) Sex of the flower -- some auxins as specific as to male or female flowers

d) Temperature treatment of seeds following treatment

h. Dormancy and storage

1) Need for dormancy control

a) Induce dormancy

b) Break dormancy

c) Regulate activity during storage (sprouting especially)

2) Regulation attained and controlled by

a) Concentration of plant regulator

b) Mixing fruits with paper shreds containing auxin

c) Spraying foliage of the plants before harvest

d) Dust applied directly to stored crop

e) Temperature of storage

f) Kind of auxin used

g) Variety and species treated

3) Auxins inhibit molds and pathogens in storage.

Suggested Teaching-Learning Activities

1. Duplicate the original experimentations with Avena.

2. Design demonstrations to show the effects of plant regulators in each of the six general classes of plant response.

3. Conduct experiments with the class to show the effects of plant regulators upon rooting, parthenocarpy, fruit setting, flower thinning, pre-harvest drop and dormancy. Vary varieties, concentrations, stages of growth, temperature, and other factors of growth as is possible.

4. Invite local grower or chemical technician to relate experiences with plant regulators to the class.

Suggested Instructional Materials and References

Texts - References:

Bonner, James, Plant Biochemistry, Academic Press, Inc., New York, N. Y., 1950.

Leopold, Carl A., Auxins and Plant Growth, University of California Press, Berkeley, California, 1955.

Skoog, F., Plant Growth Substances, University of Wisconsin Press, Madison, Wisconsin, 1951.

Tuckey, H. B., Plant Regulators in Agriculture, John Wiley & Sons, Inc., New York, N. Y., 1954.

VI. To develop skills and abilities needed by technicians in the use of chemicals to secure specific modifications of plant growth and production.

Teacher Preparation

Subject Matter Content

1. Planning a program in the use of plant regulators

   Note: The activities of technical workers in the field of plant regulators must ultimately lead to the formulation of an action program. The ability to make practical applications of theoretical understandings is required of these workers. There are no patent approaches to program planning, but a few guidelines can be suggested to direct the process.

   The field of plant regulators is one of the newest and most rapidly developing in agricultural chemicals technology. In such a setting, the technology and practices accepted today may not be acceptable tomorrow. This unit is directed toward stimulating the student to think and act in an organized manner, to consider all of the salient points which have a bearing upon a situation, and to determine a defensible course of action.

   a. Program planning -- guidelines

      1) Determine what the situation is (or apt to be if no use of plant regulators is made).

      2) Decide what is desired - determine needs, establish goals and objectives.

      3) Devise a plan of action - consider priorities, allocate resources.

      4) Put plan into action

      5) Evaluate results

2. Determine what is or is likely to be if no use of plant regulators is made. Make the determination in terms of:

   a. Growth

      1) Roots

      2) Leaves

3) Stems

4) Fruits/flowers

5) General vigor of plant

b. Yields

1) Time

2) Quantity

3) Quality (for immediate use, for deferred use)

c. Inputs

1) Labor

2) Fertilizer, soil additives

3) Disease, weed, insect control

4) Irrigation

5) Harvesting

6) Other cultural operations

7) Machinery and equipment requirements

3. Establish goals and objectives. Remember that sound goals and objectives must be (1) worthwhile, (2) obtainable, (3) measureable, and (4) challenging. Maximization of net income is primary incentive although others are important. Some of the considerations which need to be made include:

a. The crop

1) What responses are possible with the species and varieties under consideration through the use of plant regulators?

2) What qualitative and quantitative results can be expected?

3) What risk is involved - long-range effects; short-range?

b. Inputs

1) Fitting the operation in with other farming activities

2) The availability of capital, labor, machinery and equipment, and materials needed

3) Impact upon other inputs - water, fertilizer, cultural operations

c. Others

1) Market price, location, preference

2) Alternative courses of action

3) Likes and dislikes of operator

4. Devise a plan of action and apply (ways and means)

a. Assign priorities and allocate resources

1) Determine the use or uses to be made of plant regulators

2) Make a selection of the chemical or chemicals to be used

3) Make preparations for the use of the regulator

a) Prepare the plants/seeds

b) Prepare the chemical materials

c) Use the appropriate method of application

d) Control as many of the variables as possible which have a bearing on the use of plant regulators

b. Anticipate problems frequently encountered in the field and prepare to treat if they materialize.

5. Evaluate results

a. Evaluate in terms of goals and objectives

6. Example of a planned program using a plant regulator

a. Cotton defoliation

1) Why defoliate

a) Higher grades of cotton

b) Facilitates harvesting

c) Aids lodged plants to straighten up

d) Increase exposure to sun and air

e) Reduction of boll rot

f) Reduces insects

2) Factors related to effectiveness of defoliation

a) Factors promoting defoliation

-- Temperature high

-- Plants in cut-out

-- Complete coverage by defoliant

-- Large droplets

-- Soil fertile but nitrogen exhausted at time of defoliation

-- Soil moisture moderately high and uniform throughout season, and moderate at time of defoliation

-- Plant population uniform, 20,000 to 70,000 per acre

-- Insects controlled

-- Weeds controlled

-- Land uniform

b) Factors hindering defoliation

-- Temperature low

-- Plants growing

-- Coverage incomplete

-- Fog or small droplets

-- Low fertility or high nitrogen at time of defoliation

-- Soil moisture low or irregular, either very low or very high at time of defoliation

-- Plant population varied, or excessive

-- Insects uncontrolled

-- Weeds uncontrolled

-- Land uneven, saline, or alkaline

3) When and how to defoliate using cotton as the example

a) Timing: Commercial defoliants have no known harmful effect on fully developed fiber and seed such as that of cotton. But development of both fiber and seed stops with the application of a defoliant so that premature application is followed by defective immature fiber and low quality seed. In the case of cotton, immature fibers are high in sugar and sticky as well as low in strength, leading to serious difficulties in spinning, weaving, and in dyeing. However, early application does reduce boll rot, and if application is so late that the weather is cool and the plants are dry and very mature, response to defoliant will be reduced and slow. While the time required for full maturity of fiber varies with temperature and other conditions, in general at least 40 days after bloom are necessary.

RULE OF THUMB: If a boll can be easily cut through it is not mature. If the fiber "strings" when the boll is cut, and the youngest bolls cannot be dented by pressure between thumb and two fingers, it is usually safe to apply defoliant.

The harvest program is also important in the timing of application. Mature bolls open rapidly after the leaves fall and harvest should follow very soon. Otherwise, fiber may deteriorate, and fiber may be stained by tender second-growth leaves during picking. If your picking facilities are limited, stagger applications.

When to apply defoliant is therefore a question which you must decide, considering all the factors mentioned above. If conditions force a decision between early application with possible injury to fiber and seed, and late application with possible poor leaf fall, it is better to apply late and insure high quality fiber and seed as well as higher yields. Seventy per cent of the bolls should be open at time of application.

b) Method: You can apply defoliants by ground machines or airplanes. With aerial application, use a flagman to ensure complete coverage. Rank cotton often requires split applications, the second application after the upper leaves have fallen.

High clearance ground machines fitted with fenders and boom-drop nozzles are being used increasingly in the application of defoliants.

Relatively low pressure (25 pounds per square inch) and nozzles producing relatively large droplets have given excellent results in recent tests. The nozzels should be placed so that the spray reaches the plant when they are spread, not compressed by the machine.

c) Bottom defoliation: When the cotton is rank and conditions favor boll rot, you may wish to consider early bottom defoliation. This must be done by ground machine, directing the spray to the lower third of the plant. Early bottom defoliation reduces boll rot, retards or kills weeds, and permits early picking of the bottom crop. Be careful that the defoliant does not reach regions of the plant where bolls are immature as the defoliant stops development of fiber and seed.

d) Use of desiccants: Dessication is practiced to some extent to kill second growth after application of a defoliant. Because of their severe action on plant tissues, desiccants should not be used on immature cotton. The crop should be fully matured at date of application to avoid immature fiber and seed.

e) Limitations of defoliation

-- Plant maturity: Defoliation of the entire plant is practical only with mature plants in cut-out. Actively growing leaves are usually impossible to defoliate. Likewise, plants under moisture stress defoliate poorly.

-- Immature bolls: Plant function ceases with the application of defoliant, stopping development of both fiber and seed. When defoliants are applied before bolls are mature (less than 40 days after flowering) low-quality cotton results; fibers remain low in weight and retain sugars. Such fibers are sticky and a serious source of trouble in spinning. Seeds also remain low in weight, or poor quality and low germination. Defoliation does not accelerate the opening of immature bolls.

-- Field uniformity: Fields with irregular growth and development give irregular and incomplete defoliation. This difficulty is most frequently in areas of soil diversity, at lower ends of fields, and along borders.

4) Applying defoliants

a) Recommended rates of application

Defoliant	Recommended Rates in pounds of active ingredient per acre
Calcium cyanamid (Will not work without dew)	15 - 25
Magnesium chlorate	2.5 - 3.5
Magnesium chlorate hexahydrate	4.5 - 6.0
Sodium chlorate (Very dangerous unless mixed with fire suppressant)	2.5 - 4.5
S.S.S. - Tributyl phosphorotrithioate	1.25 - 1.5
Tributyl phosphorotrithioite	1.25 - 1.5

Use LOW RATES with small plants early in the season or in warm weather.

Use HIGH RATES with large plants, late in season or cool weather.

b) Application: By AIR, apply defoliant in 8-10 gallons of water per acre. By GROUND MACHINE, the volume of water required for effective application depends on the machine. Machines using low pressure with large droplets have given excellent defoliation at 25 gallons per acre. With high pressure and small droplets as much as 60 gallons may be required.

c) Additives: The use of surfactants (also called spreaders and activators) has sometimes improved defoliation, particularly when conditions such as moisture stress or cool weather are generally unfavorable for defoliation.

Suggested Teaching-Learning Activities

1. Have members of the class select for study specific plant regulators for use on various crops to achieve different responses. Gather information relative to approved practices and recommendations and summarize for class distribution.

2. Demonstrate various methods by which plant regulators are applied.

3. Use flip charts which show various kinds and concentrations of plant regulators to use in order to secure various responses and also how each of the chemicals is affected by different environmental factors.

Suggested Instructional Materials and References

Texts - References:

Bonner, James, Plant Biochemistry, Academic Press, Inc., New York, N. Y., 1950.

Leopold, Carl A., Auxins and Plant Growth, University of California Press, Berkeley, California, 1955.

Skoog, F., Plant Growth Substances, University of Wisconsin Press, Madison, Wisconsin, 1951.

Tuckey, H. B., Plant Regulators in Agriculture, John Wiley & Sons, Inc., New York, N. Y., 1954.

Appropriate State Extension Service Bulletins, Leaflets, and Circulars.

Selected Commercial Literature from Leading Chemical Firms.

VII. To acquire knowledge and skills needed to lawfully and safely handle, transport, store, and apply chemicals as plant regulators.

Teacher Preparation

Subject Matter Content

1. The concern for safety and the need for laws and controls in the field of plant regulators

   a. The technical nature of the agricultural chemicals industry requires that rigid controls and regulations be instituted in the public interest. To safeguard this interest, controls and regulations are needed to:

      1) Protect against adulteration of foodstuffs and fibers.

      2) Insure a satisfactory margin of safety for those who work with such chemicals.

      3) Minimize the danger or harmful effects to other useful plants and animals.

      4) Protect humans against direct or indirect exposures.

      5) Protect the public against misleading or false statements concerning a product.

   b. When plant regulators are used in prescribed ways and in prescribed amounts, they present no known danger to man or his environment.

2. Provisions of the laws, regulations and controls pertaining to the manufacture, sale, and use of chemical plant regulators

   a. The use of agricultural chemicals has been regulated for many years by federal and state laws. The first federal legislation dealing with them was passed in 1910. (The Federal Insecticide Act.) Since then, additional laws and modifications of existing laws have kept pace with changing needs.

   b. Nematocide, Plant Regulator, Defoliant, and Desiccant Amendment of 1959

      This Act amends the Federal Insecticide, Fungicide, and Rodenticide Act (1947) so as to include nematocides, plant regulators, defoliants, and desiccants. The 1947 Act requires, in general, that economic poisons (includes

plant regulators under the 1959 Act) shipped in interstate be registered with the U.S.D.A. In order to have a product so registered, the manufacturer must submit proof that the chemical will safely and effectively accomplish the purpose for which it is manufactured, when used in accordance with instructions developed for its use. A study of these two Acts is recommended.

c. The Miller Amendment (1954) to the Federal Food, Drug and Cosmetic Act (1938)

This Act requires tolerances for pesticide residues in or on raw agricultural products and makes it illegal to sell such food products with residues in excess of these stipulated tolerances in interstate commerce.

d. Most states (43 out of 50) have passed a "Uniform State Act" or other legislation requiring that pesticides conform to stipulated safety standards in order to be registered and sold within the state. These state laws give the manufacturer, the user, and the public a measure of protection. Registration serves as a screen to prevent ineffective, fraudulent, or dangerous economic poisons from being marketed in the state. It helps enforcement and permits correction of unsatisfactory or illegal labeling before a product enters trade.

e. Publishing the analysis of official samples serves as a strong deterrent to the sale of adulterated materials.

3. Working with plant regulators

a. Responsibility for the use of chemicals on a farm or ranch resides primarily with the owner; however, applicators are liable for the use of unsafe materials and improper manner in which they are applied.

1) Growth regulators, by comparison to other agricultural chemicals, are relatively safe to work with. The greatest risk of not achieving satisfactory results from their use lies in the failure to use the proper chemical, in the correct concentration, at the appropriate time, and under optimum conditions of weather and stage of growth.

2) Because of higher rates required, dusts usually drift worse than sprays.

b. Storing -- crystalline indoleacetic acid should not be stored over two or three years because it breaks down and loses its purity and activity. Aqueous indoleacetic acid loses its effectiveness in a short period of time--3-10 days.

Breakdown of auxins other than the indole series is much slower and storage precautions are less important.

c. Application -- the problem of drift, failure to secure proper application, and disregard for the persistence of plant regulators in both plants and the soil are most often encountered.

Before using any plant regulator, study carefully all manufacturer's instructions. Improperly handled, some regulators are hazardous to workers, equipment, or nearby crops.

Chlorates are potential fire and explosion hazards. Chlorates defoliants, as commercially formulated, are relatively safe, but no untrained person should attempt to formulate chlorates. Fires have resulted from the chance mixing of chlorate defoliants and organic insecticides.

Suggested Teaching-Learning Activities

1. Invite a representative of the Department of Agriculture of your state to speak on the provisions of federal and state laws and controls which pertain to plant regulators.

2. Have the class secure copies of the legislative provisions in your state which regulate the use of growth regulators. A class project, by committee assignment, would be to analyze and summarize the most significant provisions of the laws and regulations.

3. Secure labels from the containers of different kinds of plant regulators. Study the manufacturer's recommendations and also note how each firm has complied with labeling and registration provisions by furnishing various information on the container.

4. Take a field lab to a local farm to observe and study the procedures followed in handling and working with plant regulators.

5. Make field appliaations of plant regulators on demonstration plots.

Suggested Instructional Materials and References

1. Materials and equipment necessary to make field applications of plant regulators.

2. State and federal safety codes and regulations.

3. State and federal legislation and enactments - especially

   a. 1959 Amendment to Federal Insecticide, Fungicide, and Rodenticide Act.

   b. The (1947) Federal Insecticide, Fungicide, and Rodenticide Act.

   c. The Miller Amendment (1954) to the Federal Food, Drug, and Cosmetic Act.

4. Labels, used containers of plant regulator materials.

5. State Industrial Safety Commission posters and accident reports.

Suggestions for Evaluating Educational Outcomes of the Course

1. Employer evaluations of the quality of work done by the student on the job. Check lists should be used.

2. The student should be asked to rate themselves.

3. Evaluation of cooperating supervisors in the occupational experience center may be used.

4. Student performance on a term problem, in examinations, and giving reports.

Source of Suggested Instructional Materials and References for the Course

Audus, L. J., "Plant Growth Substances," Interscience Publishers, Inc., New York, 1953.

Audus, L. J., Plant Growth Substance, Leonard Hill Books Limited, London, 1959.

Bonner, James, Plant Biochemistry, Academic Press, Inc., New York, N. Y., 1950.

Crocker, William, Growth of Plants, Reinhold Publishing Corp., New York, N. Y., 1948.

"The Economics of Cotton Defoliation," Mississippi State College, Agricultural Experiment Station, Bulletin 552, 1957.

"Effect of Cotton Defoliation on Yield and Quality," Production Research Report No. 46, U.S.D.A. Agricultural Research Service, 1961.

Handbook on Aerial Application in Agriculture, Short Course Office, A and M College of Texas, College Station, Texas, 1956.

Leopold, Carl, Auxins and Plant Growth, University of California Press, Berkeley and Los Angeles, 1955.

Lomis, W. C., "Growth and Differentiation in Plants," The Iowa State College Press, Ames, Iowa, 1949.

Paleg, L. G., "Physiological Effects of Gibberellins," Annual Review of Plant Physiology, Vol. 16, 1965, Annual Review Inc., Palo Alto, California, 1965, pp. 291-327.

Parihar, N. S., Hormonal Control of Plant Growth, Asia Publishing House, Bombay, 1961.

Plant Growth Regulation, Fourth International Conference on Plant Growth Regulation, The Iowa State University Press, Ames, Iowa, 1961.

Sargent, J. A. "The Penetration of Growth Regulators Into Leaves," Annual Review of Plant Physiology, Vol. 16, 1965, Annual Reviews Inc., Palo Alto, California.

Skoog, F., Plant Growth Substances, University of Wisconsin Press, Madison, Wisconsin, 1951.

Thompson, W. T., Agricultural Chemicals Book III--Fumigants, Growth Regulators, Repellents, and Rodenticides, The Simmons Publishing Co., Davies, California, 1965.

Tukey, H. B., Plant Regulators in Agriculture, John Wiley & Sons, Inc., New York, N. Y., 1954.

The Superintendent of Documents, Washington, D.C. (Federal Acts)

Wain, R. L., The Chemistry and Mode of Action of Plant Growth Substances, Academic Press, Inc., New York, N. Y., 1956.

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INSTRUCTOR NOTE: As soon as you have completed teaching each module, please record your reaction on this form and return to the above address.

1. Instructor's Name_____

2. Name of school_____State_____

3. Course outline used: _____Agriculture Supply--Sales and Service Occupations
   _____Ornamental Horticulture--Service Occupations
   _____Agricultural Machinery--Service Occupations

4. Name of module evaluated in this report_____

5. To what group (age and/or class description) was this material presented?____
   _____

6. How many students:
   a) Were enrolled in class (total) _____
   b) Participated in studying this module _____
   c) Participated in a related occupational work experience program while you taught this module _____

7. Actual time spent teaching module:

		Recommended time if you were to teach the module again:
_____hours	Classroom Instruction	_____hours
_____hours	Laboratory Experience	_____hours
_____hours	Occupational Experience (Average time for each student participating)	_____hours
_____hours	Total time	_____hours

(RESPOND TO THE FOLLOWING STATEMENTS WITH A CHECK (✓) ALONG THE LINE TO INDICATE YOUR BEST ESTIMATE.)

	VERY APPROPRIATE	NOT APPROPRIATE
8. The suggested time allotments given with this module were:		
9. The suggestions for introducing this module were:		
10. The suggested competencies to be developed were:		
11. For your particular class situation, the level of subject matter content was:		
12. The Suggested Teaching-Learning Activities were:		
13. The Suggested Instructional Materials and References were:		
14. The Suggested Occupational Experiences were:		

(OVER)

15. Was the subject matter content sufficiently detailed to enable you to develop the desired degree of competency in the student? Yes_____No_____
Comments:

16. Was the subject matter content directly related to the type of occupational experience the student received? Yes_____No_____
Comments:

17. List any subject matter items which should be added or deleted:

18. List any additional instructional materials and references which you used or think appropriate:

19. List any additional Teaching-Learning Activities which you feel were particularly successful:

20. List any additional Occupational Work Experiences you used or feel appropriate:

21. What do you see as the major strength of this module?

22. What do you see as the major weakness of this module?

23. Other comments concerning this module:

_____ _____
(Date) (Instructor's Signature)

_____
(School Address)